INTEGRATED START-UP CIRCUIT WITH REDUCED POWER CONSUMPTION

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention generally relates to power supplies. More particularly, the present invention relates to the start-up circuit of a switching power supply.

Description of the Prior Art

[0002] Switching mode power supplies have largely replaced linear transformers and linear power supplies. Switching mode power supplies have grown in popularity, because they are more cost effective than linear power supplies. Furthermore, they offer several other advantages over linear power supplies, including reduced size, improved efficiency, and higher performance.

[0003] However, the start-up circuitry commonly used by switching mode power supplies can be substantially improved.

[0004] Several passive start-up devices known in the prior arts include U.S. Patents **5,200,886** (Karl Schwarz, Horst Bartussek, Helmut Rettenmaier), **5,262,933** (Chen Shyi-Hon), **5,452,195** (Steffen Lehr, Volker Neiss, Jose I. Rodriguez-Duran, Rudolf Koblitz), and **6,069,805** (Wayne Anderson). The main drawback of these circuits is high power consumption.

[0005] Start-up circuits using high-voltage transistors are also well known in the prior arts. Examples of such start-up circuits are disclosed in U.S. Patents **5,200,886** (Karl Schwarz, Horst Bartussek, Helmut Rettenmaier), **6,002,598** (Erwin G. R. Seinen,

Naveed Majid), and **6,480,402** (Claudio Adragna, Claudio Spini). The drawback of these start-up circuits is also high power consumption because they require primary-side protection circuits.

[0006] In recent years, the manufacturers of computers and other types of equipment have been striving to comply with increasingly stringent environmental regulations. US and European regulations regarding electrical appliances strictly limit the amount of power that is consumed by supervising circuits and remote-control circuits. Reducing standby-mode power consumption has become a major concern. The start-up circuits of known power supplies are a major source of power loss. Furthermore, because traditional power supplies typically have high power consumption under light-load and zero-load conditions, it is increasingly difficult to manufacture electrical appliances that are compliant with environmental regulations.

[0007] FIG. **1** shows the input circuit of a prior-art switching mode power supply based on U.S. Patent Application Number 10/065,530 (Yang Ta-yung). In order to comply with safety regulations, a bleeding resistor **20** is used to discharge the energy that is stored in an EMI filter **10**. A bridge rectifier **30** and an input capacitor **40** rectify and filter the AC input source $\mathbf{V_{AC}}$ into a DC voltage $\mathbf{V_{IN}}$. A transformer **50** is connected to the input capacitor **40**. The transformer **50** is also connected in series with a power transistor **80**. A control-circuit **100** is used to regulate the power supply. When the AC input source $\mathbf{V_{AC}}$ is applied to the power supply, a start-up capacitor **43** will be charged via a start-up resistor **61**. The start-up capacitor **43** provides a supply voltage $\mathbf{V_{CC}}$ to power the control-circuit **100**. The control-circuit **100** comprises an ON/OFF circuit **105**, a line-voltage detector (LVD) **120**, a latch circuit **150**, a PWM (pulse width modulation) circuit **170**, and a protection circuit **190**. Once the supply voltage $\mathbf{V_{CC}}$ provided by the

start-up capacitor **43** exceeds a start-threshold voltage, the ON/OFF circuit **105** will enable the control-circuit **100** to begin pulse width modulation (PWM) operation.

[0008] After that, an auxiliary winding of the transformer **50** will power the control-circuit **100** via a diode **65**. If the supply voltage V_{CC} drops below a stop-threshold voltage, the ON/OFF circuit **105** will shut down the PWM operation of the control-circuit **100**.

[0009] The PWM circuit **170** generates a PWM signal to switch the power transistor **80**. When the power transistor **80** is switched on, the primary current of the transformer **50** will produce a current-sense voltage V_S across a resistor **85**. A line current I_{IN}, which can represents the line voltage information, is provided to the line-voltage detector **120**. The line-voltage detector **120** accepts the line current I_{IN} via a detection resistor **62** connected to the input capacitor **40**.

[0010] The control-circuit **100** includes the protection circuit **190**. The protection circuit **190** will terminate the PWM signal in response to various protection conditions, including over-voltage protection, over-temperature protection, and over-power protection. The line current I_{IN} and the current-sense voltage V_S are used to provide over-power protection. After the protection circuit **190** signals the latch circuit **150**, the power supply will be locked in an off state. By disconnecting the AC input source V_{AC} and discharging the input capacitor **40**, the latch circuit **150** can be reset, so that it will be ready to restart the power supply. Unfortunately, the input capacitor **40** usually has a large capacitance that may take several minutes to completely discharge. To solve this problem, a resistor **63** and a high-voltage transistor **64** are included to accelerate the discharge of the input capacitor **40**. However, the bleeding resistor **20**, the start-up resistor **61**, and the detection resistor **62** consume significant amounts of power. The

power consumption of resistors **61** and **62** is equal to V_{IN}^2/R. If an increase in the magnitude of the AC input source occurs, the extra power loss will increase dramatically, especially with a 240V AC input.

[0011] Thus, the principle drawback of the power supply shown in FIG. **1** is higher power consumption. Another drawback is the need for extra discharge devices such as the resistor **63** and the high-voltage transistor **64**. Adding these parts will further increase the cost of the power supply.

SUMMARY OF THE INVENTION

[0012] The present invention provides a control-circuit for a switching mode power supply. The control-circuit integrates a start-up circuit, a latch circuit and a line-voltage detector to reduce power consumption. The start-up circuit according to the present invention can start up the power supply using a low start-up current. Therefore, no extra discharge device is required and the cost of the power supply can be reduced.

[0013] Briefly, the control-circuit according to the present invention uses a bleeding resistor to discharge an EMI filter and to charge up a start-up capacitor. The start-up capacitor is charged up from the AC input terminals via the bleeding resistor. Because the voltage of the input capacitor does not affect the operation of the control-circuit, no extra discharge device is needed to accelerate the discharge of the input capacitor. The latch circuit can be quickly reset once the AC input is shut off. After the control- circuit starts to operate, an auxiliary winding of the transformer will provide energy to power the control-circuit.

[0014] A principle advantage of the control-circuit according to the present invention is reduced power consumption. No resistors or transistors need to be connected to the

input capacitor for start-up and line-voltage detection, since the auxiliary winding of the transformer generates a bias voltage for line-voltage detection. Furthermore, an ON/OFF circuit can detect the supply voltage and start PWM operation with a smaller start-up current than most prior-art power supplies.

[0015] The present invention integrates the start-up circuit, the latch circuit, and the line-voltage detector to reduce power consumption. Moreover, no extra device is required to accelerate the discharge of the input capacitor. Because of this, the control-circuit for a switching mode power supply according to the present invention can be built at a lower manufacturing cost than prior-art power supplies.

[0016] It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

[0018] FIG. **1** shows an input circuit of a traditional switching mode power supply.

[0019] FIG. **2** shows an input circuit of a power supply according to the present invention.

[0020] FIG. **3** shows an ON/OFF circuit according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] FIG. **2** shows an input circuit of a power supply according to the present invention. An AC input source V_{AC} is supplied to a first AC input and a second AC input of a bridge rectifier **30** via an EMI filter **10**. An output of the bridge rectifier **30** is connected to an input capacitor **40** to produce a DC input voltage V_{IN}. A transformer **50** is coupled to the input capacitor **40**. A power transistor **80** is used for switching the transformer **50**.

[0022] The power supply includes a control-circuit **200**, which comprises an ON/OFF circuit **110**, a line-voltage detector (LVD) **120**, a latch circuit **150**, a PWM circuit **170**, a protection circuit **190**, and two mirror transistors **91** and **92**. A supply voltage V_{CC} supplies power to the control-circuit **200**. The ON/OFF circuit **110** starts up PWM operation whenever the supply voltage V_{CC} exceeds a start-threshold voltage. When the supply voltage V_{CC} drops below a stop-threshold voltage, the ON/OFF circuit **110** will disable PWM operation.

[0023] The PWM circuit **170** cooperates with the line-voltage detector **120** and the protection circuit **190** to control PWM operation. The PWM circuit **170** regulates the output voltage by producing a PWM signal to switch the power transistor **80**. When the power transistor **80** is switched on, the primary current of the transformer **50** will produce a current-sense voltage V_S across a resistor **85**. The current-sense voltage V_S is supplied to the line-voltage detector **120**, to provide an over-power signal to the protection circuit **190**. The protection circuit **190** provides the power supply with over-voltage, over-temperature, and over-power protection functions. The latch circuit **150** is connected in parallel with a start-up capacitor **47**. Once the protection circuit **190** signals the latch circuit **150**, the power supply will be locked up in an off state.

[0024] A first bleeding resistor **21** is connected from the first AC input of the bridge rectifier **30** to the start-up capacitor **47**. A second bleeding resistor **22** is connected from the second AC input of the bridge rectifier **30** to the start-up capacitor **47**. To ensure safe operation, the first bleeding resistor **21** and the second bleeding resistor **22** will discharge the EMI filter **10** after the AC input source $\mathbf{V_{AC}}$ is turned off. Once the power supply is turned on, the input capacitor **40** will be charged up to the DC input voltage $\mathbf{V_{IN}}$ within a few AC cycles. In the meantime, the AC input source $\mathbf{V_{AC}}$ will begin to charge the start-up capacitor **47** via the first bleeding resistor **21**, the second bleeding resistor **22**, and the bridge rectifier **30**.

[0025] When the supply voltage $\mathbf{V_{CC}}$ of the start-up capacitor **47** exceeds the start-threshold voltage, the ON/OFF circuit **110** will enable PWM operation. Since the bleeding resistors **21** and **22** are connected to the AC input terminals, the start-up capacitor **47** will be charged by the AC input source. After PWM operation starts, an auxiliary winding of the transformer **50** will power the supply voltage $\mathbf{V_{CC}}$ via a diode **71** and a diode **75**.

[0026] A first terminal of the auxiliary winding is connected to a capacitor **45**. The first terminal of the auxiliary winding is further connected to an anode of the diode **75**. A cathode of the diode **75** is connected to the start-up capacitor **47** to power the supply voltage $\mathbf{V_{CC}}$. A second terminal of the auxiliary winding is connected to a cathode of the diode **71**. An anode of the diode **71** is grounded. The second terminal of the auxiliary winding is further connected to a resistor **73**. The resistor **73** is connected to a capacitor **49** to produce a bias voltage. The bias voltage is converted into a bias current via a resistor **25**. The bias current drives a source of the mirror transistor **91** and a source of the mirror transistor **92**. A gate of the mirror transistor **91**, a gate of the mirror transistor

92, and a drain of the mirror transistor **91** are tied together. In response to the bias current, the drain of the mirror transistor **91** generates a first proportional current $\mathbf{I_A}$. The first proportional current $\mathbf{I_A}$ and the supply voltage $\mathbf{V_{CC}}$ are both supplied to the start-up capacitor **47**. A drain of the mirror transistor **92** provides a second proportional current $\mathbf{I_B}$ to the line-voltage detector **120** for line-voltage detection. Since the bias voltage is much lower than the DC input voltage $\mathbf{V_{IN}}$, the power consumption of the resistor **25** will not be significant. To further reduce power consumption, most of the current used for line-voltage detection is recycled to provide the supply voltage $\mathbf{V_{CC}}$.

[0027] When the AC input source $\mathbf{V_{AC}}$ is shut off, the bleeding resistors **21** and **22** will discharge the EMI filter **10**. Discharging the start-up capacitor **47** can quickly reset the latch circuit **150**. However, the voltage across the input capacitor **40** does not affect the operation of the latch circuit **150**. Therefore, no discharge device is needed to accelerate the discharge of the input capacitor **40**.

[0028] FIG. **3** shows the ON/OFF circuit **110** according to one embodiment of the present invention. The ON/OFF circuit **110** is used to detect the magnitude of the supply voltage $\mathbf{V_{CC}}$ and enable PWM operation, while consuming very little start-up current. In the ON/OFF circuit **110**, two zener diodes **310** and **311** are connected in series with three resistors **321**, **322**, and **323**. The supply voltage $\mathbf{V_{CC}}$ is supplied to a cathode of the zener diode **310**. The resistor **323** is connected to the ground reference. A gate of an n-transistor **315** is connected to a junction of the resistors **321** and **322**. A source of the n-transistor **315** is connected to the ground reference. A drain of the n-transistor **315** is connected to a gate of a p-transistor **316**. A source and a drain of the p-transistor **316** are connected in parallel with the zener diode **310**. A resistor **325** is connected between the source of the p-transistor **316** and the gate of the p-transistor **316**. The drain of the n-

transistor **315** is further connected to an input of an inverter **351**. An output of the inverter **351** is connected to an input of an inverter **352**.

[0029] An output of the inverter **352** drives a gate of a p-transistor **319**. A source of the p-transistor **319** is supplied with the supply voltage $\mathbf{V_{CC}}$. A drain of the p-transistor **319** produces a power voltage $\mathbf{V_{DD}}$. As the p-transistor **319** is turned on, the power voltage $\mathbf{V_{DD}}$ will be supplied to the PWM circuit **170**, the protection circuit **190**, and the line-voltage detector **120**. This will start PWM operation. The output of the inverter **352** further drives a gate of an n-transistor **317**. A drain of the n-transistor **317** is connected to a junction of the resistor **322** and the resistor **323**. A source of the n-transistor **317** is connected to the ground reference. The n-transistor **317** is turned on whenever the n-transistor **315** is turned off and vice-versa. Once the supply voltage $\mathbf{V_{CC}}$ exceeds the sum of the voltages of the zener diodes **310** and **311**, a current will flow into the resistors **321** and **322**. This will generate an entry voltage at the gate of the n-transistor **315**. When the entry voltage exceeds the gate-threshold voltage of the n-transistor **315**, the p-transistor **316** will be turned on.

[0030] Turning on the p-transistor **316** will short-circuit the zener diode **310** and increase the entry voltage. In the meantime, turning on the p-transistor **315** will turn off the n-transistor **317**. A turn-off signal will propagate through the inverters **351** and **352**. Turning off the n-transistor **317** will form a positive feedback signal, to switch on the n-transistor **315**. The start-threshold voltage of the ON/OFF circuit **110** is the sum of the voltage of the zener diode **310**, the voltage of the zener diode **311**, and the gate-threshold voltage of the n-transistor **315**. The stop-threshold voltage is the sum of the voltage of the zener diode **311** and the gate-threshold voltage of the n-transistor **315**. When the supply voltage $\mathbf{V_{CC}}$ drops below the stop-threshold voltage, this will turn off

the n-transistor **315**, and the p-transistors **316** and **319**. Meanwhile, the n-transistor **317** will be turned on and PWM operation will be halted.

[0031] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims or their equivalents.